# Uncertainty in Competitive Bidding – A Framework for Product-service Systems

Melanie E. Kreye[1]*, Linda B. Newnes[1], Yee Mey Goh[2]

*1) Department of Mechanical Engineering, University of Bath, Bath, UK*

*2) Wolfson School of Mechanical and Manufacturing Engineering, Loughborough University, Loughborough, UK*

* Corresponding author. Mail: University of Bath, Claverton Down, Bath, BA2 7AY, UK. Email: m.kreye@bath.ac.uk. Tel.: 44 (0)1225 385366, Fax: +44 (0)1225 386928.

# Uncertainty in Competitive Bidding – A Framework for Product-service Systems

Because of servitisation, manufacturing companies are increasingly required to compete through the provision of services around their products. The contracts for these services are often allocated through competitive bidding where the potential suppliers submit a price bid to the customer. The pricing decision is influenced by various uncertainties. This paper proposes a conceptual framework depicting these influencing uncertainties on the bidding strategy. This framework is based on three empirical studies with industry investigating different viewpoints on the decision-making process. The intention is to support the pricing decision when competitively bidding for a service contract. The framework can be applied to specific competitive bidding situations to identify the influencing uncertainties, model them and depict their influences on the pricing decision.

Keywords: uncertainty, bidding strategy, competitive bidding, pricing, decision making

## 1. Introduction

Sustainable production and consumption have become more important internationally which has led to the transformation of market structures and competitive situations into the direction of servitisation, i.e. the provision of services as opposed to products [Baines et al., 2009; Neely, 2008; Oliva and Kallenberg, 2003]. Based on Vargo and Lusch, a service is defined as the use of specialised competences through its application in processes, activities and performances to achieve a benefit [Vargo and Lusch, 2004; Maguire et al., 2012]. As such, a product-service system is a marketable, integrated combination of products and services, which extends the traditional functionality of a product by incorporating additional services [Baines et al., 2009; Aurich et al., 2006]. Examples are the supply of the number of flying hours for an aircraft [BAE, 2012] and the support of a submarine through life [Rolls-Royce, 2011a]. This means that companies that traditionally design and manufacture long-life products now compete through the provision of a service.

These companies face a high level of uncertainty due to the novelty of the process and the long-term nature of services. For example, in Rolls-Royce's Flotilla Support Programme for their submarines service contracts have been agreed until 2017 [Rolls-Royce, 2011b]. For this research uncertainty is defined as a potential deficiency in any phase or activity of the process, which can be characterised as not definite, not known, or not reliable [Soanes, 2005; Huyse and Walters, 2001]. Within this context, forecasting can be used to reduce this uncertainty and support decision-making [Durango-Cohen and Yano, 2011; Lawrence et al., 2006]. An example is the estimation of the maintenance cost of a product [Fornasiero et al., 2012]. However, due to the nature of forecasting and the impossibility to predict the future exactly, the treatment of uncertainty is crucial.

As a consequence, it is difficult for companies to determine an appropriate price bid for the service, which will enable them to win the contract as well as make a profit [Chapman et al., 2000; Hua et al., 2012; Wang et al., 2012]. The uncertainty at the bidding stage can be related to e.g. the cost-estimate for fulfilling the contract, which may be based on different assumptions about the future. Examples are the price of spare parts and the inflation rate on the financial markets [Viceira, 2012]. Figure 1 shows an example of a cost estimate for fulfilling the contract requirements and the included uncertainty in the form of a forecast range [Tay and Wallis, 2000].

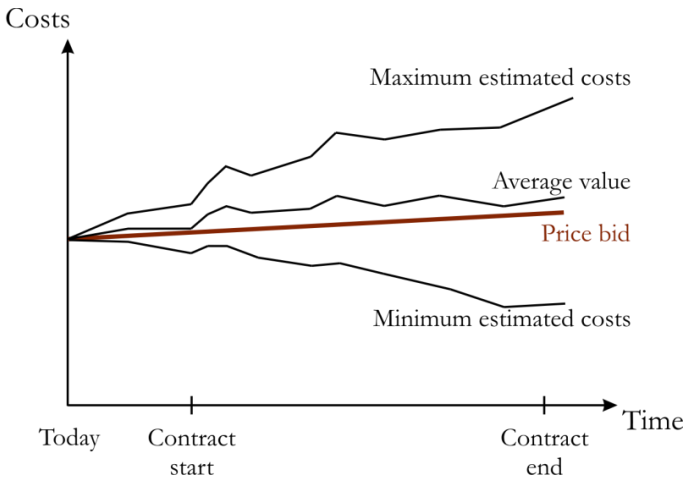


Figure 1: Example of a cost estimate and a possible price bid

At the bidding stage, the decision maker has to select one point within the given range as a price bid to communicate to the customer. One example is marked in Figure 3. Choosing a price that is too high may result in being underbid by competitors and, thus, potential loss of business [Yiu and Tam, 2006]. A too low price may influence the customer's perception of the service quality and, thus, be rejected [Huang and Lin, 2011; Freedman, 1988] or result in the failure to recover the costs or produce a profit [Monroe, 2002]. To make a pricing decision based on the previously estimated costs of the service contract, the decision maker has to understand;

- the uncertainty in the cost estimate, and
- other uncertainties that influence the bidding success and the fulfilment of the service contract.

This paper proposes a conceptual framework that aims at supporting companies that offer services in making their pricing decision under uncertainty in a competitive bidding situation. The framework displays the influencing uncertainties on the bidding strategy and pricing decision. The purpose of this framework is to support companies to identify the key uncertainties that influence their pricing decision and use this to analyse and manage them.

## 2. Literature Review - Competitive bidding in services

Literature in service operations research often highlights the importance of both the service price and quality in the decision-making processes at the competitive bidding stage [Yang et al., 2009; Agrawal and Seshadri, 2000; Freedman, 1988]. Particularly, the management of the service quality has received high interest in research [Holschbach and Hofmann, 2011]. The general consensus is that higher service quality may result in a higher customer satisfaction, which may lead to increased intention for repurchase [Holschbach and Hofmann, 2011; Heskett et al., 2008].

Literature describing the decision-making processes when bidding for a service contract typically focus on one specific influencing aspect. For example, a large body of research describes the importance of the customer, highlighting the influence of the relationship to the customer [van der Valk et al., 2009], the experience form previous service contracts on the outcome of the decision process [Holschbach and Hofmann, 2011], the level of trust between the two parties [Coughlan et al., 2011] and the influence on the customer's intention for purchase.

Other literature focuses on the importance of the supplier's position in the competitive environment [Lewis et al., 2010; Liu et al., 2011]. Typical areas of interest are the company's identification of a competitive advantage to aid the strategic decision-making process. Approaches highlighting the uncertainty in this process, particularly for service contracts, have stated that this can be reduced through the contract design [Su and Mukhopadhyay, 2012; Enquist et al., 2011]. Thus, the contract between customer and supplier can include an agreement on business performance.

Each of these approaches highlights one specific aspect and its consideration in the decision-making process at the competitive bidding stage for service contracts. Some literature highlights connections between the described aspects. For example, Grönroos

and Helle [2010] describe how a competitive advantage can be defined through improved customer relationships. However, no complete approach or framework was found that shows the possible influences and the uncertainties influencing the bidding strategy for service contracts.

Nevertheless, in literature, approaches can be found that support a company's *business* strategy, in other words, these are frameworks that support the formulation of a company's long-term vision and performance. In particular, one approach has received a high level of acceptance and recognition: the Balanced Scorecard [Al-Ashaab et al., 2011; Afuah, 2009; Haimes, 2009; Rainey, 2003; Adler, 2001; Bontis et al., 1999; Neely, 1999]. The Balanced Scorecard was introduced by Kaplan and Norton [1996] and depicts the organisational performance of a company or business which is viewed from the following four perspectives: financial, customer, internal business and learning and growth.

The financial perspective describes the link between the objectives and targets of the different business units to the financial aims of the company as a whole [Kaplan and Norton, 1996]. Approaches such as risk management, cost reduction, productivity improvement, or investment strategy have been described in this context [Tebbens et al., 2006].

The customer perspective identifies potential customers and market segments the company operates in [Kaplan and Norton, 1996]. In other words, this perspective delivers the resources for the achievement of the company's financial goals. In general, the marketing department deals with this perspective in problems such as market segmentation, customer satisfaction, or company image.

The internal business perspective deals with the company's capabilities and limitations in the context of the market, identifying the critical processes for achieving the goals. Ideally, it offers a complete internal process value chain from the innovation

process, the operations process, to the offering of post-sale services [Afuah, 2009; Kaplan and Norton, 1996].

The learning and growth perspective describes the future objectives and targets of the company and its ability to change and improve to achieve its goals within the market. It provides the basis for achieving ambitious objectives that were identified in the previous three perspectives namely financial, customer, and internal business.

The Balanced Scorecard can be depicted as a framework with its four perspectives influencing the company's vision and business strategy as depicted in Figure 2. It shows the four perspectives on a company's business strategy from the approach presented by Kaplan and Norton [1996].

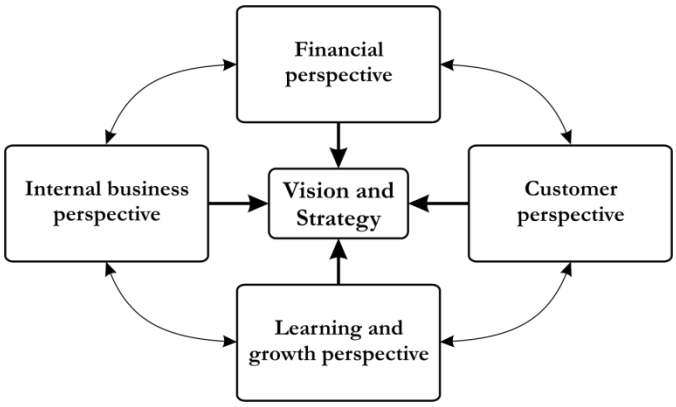


Figure 2: Framework of Balanced Scorecard with four blank perspectives (adapted from Kaplan and Norton [1996])

The general framework was used as the basis for the proposed uncertainty framework of the bidding strategy. The following section describes the methodology of the development of the proposed framework.

## 3. Methodology

To submit a competitive bid for a service contract, multiple activities have to be completed. For example, the service has to be designed, which means that the necessary

steps that constitute the service are planned and described [Goldstein et al., 2002; Berkley, 1996]. This ensures that a suitable service is provided to the customer [Baines et al., 2009]. In addition, a cost estimate has to be compiled, which describes the cost associated with the service provision [Monroe, 2002]. This research focuses on the decision-making processes based on these activities. Thus, this paper does not describe the activities necessary to define a service design and compile a cost estimate, but focuses on the decision-making process following these activities. This is depicted in Figure 3. The creation of a service design and the cost estimate are illustrated as a linear stream due to the logical causality of these activities (an activity can only be costed once it has been defined in the service design). It is noteworthy that in practice, these activities often happen in parallel; however, this difference does not influence the content of this research. This research focuses on the decision-making process at the competitive bidding stage based on the described activities, which can be made by e.g. the decision board or project managers. Thus, the service design and cost estimate form the input into the presented research.

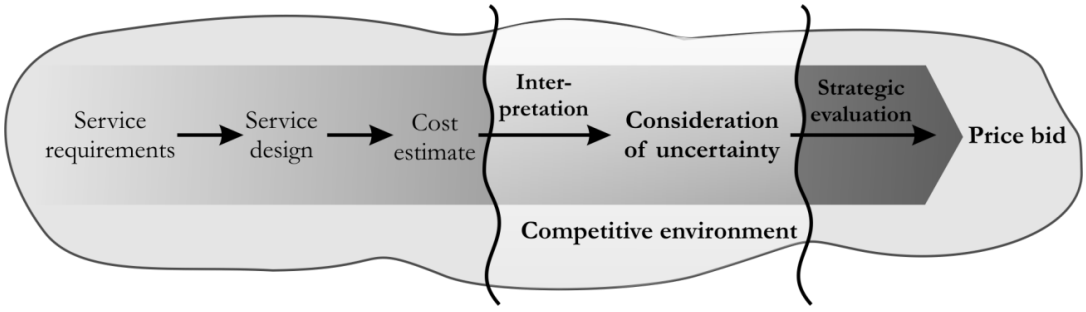


Figure 3: Decision process of bidding for a service contract

For this research, the assumption is made that a service design exists and a cost estimate is available. This research assesses the decision process starting with the interpretation of the cost estimate, in other words it focuses on the use of the cost estimate in the decision process as depicted by the framed area in Figure 3. The three parts of the decision-making

process were investigated in three separate studies.

Table 1 depicts the focus of the three studies with the specific aims and applied method.

Table 1: Focus of three empirical studies

| **Study focus** | **Aim** | **Method** |
|---|---|---|
| 1) Interpretation of cost estimate | Identification of the approach to displaying uncertain costing information for the further consideration of the uncertainty in the decision-making process. | Experimental survey of practitioners with questionnaires |
| 2) Influence of competition | Identification of the difference between the decision-making process with and without the existence of competition. | Experimental survey of practitioners with questionnaires |
| 3) Consideration of uncertainty | Investigation of the main uncertain influences that are considered in the decision-making process and the amount of available information about them. | Interview study with practitioners |

The first study investigated the interpretation of the cost estimate and focused on the influence that different approaches to displaying this information can have on the interpretation and consideration of the uncertainty connected to it. To examine this topic, an experimental survey study was conducted in the form of questionnaires because this method requires a minimal level of interaction between the researcher and participant and, thus, is bound to a minimal level of bias in the results. Different approaches to displaying uncertain costing information were shown to different groups of participants and their reactions were recorded.

The second study investigated the influence that the competitive environment has on the decision-making process and outcome. To examine this area, a second experimental study with questionnaires was conducted due to the same reasons as described above. In this study, two separate questionnaires were given to the same set of participants at different times to record their reaction to two bidding scenarios which differed in the existence of competition.

The third study examined the consideration of the uncertainty connected to the decision and availability of information at the bidding stage. As the answers may vary between companies, a more qualitative research method was applied. An interview study was considered a suitable method as it offers a basis for discussion of the particular aspect of the decision-making process and it is a flexible way of revealing strategic information.

## 4 Empirical basis of the framework

The proposed uncertainty framework for competitive bidding was based on three empirical studies with industrialists. This section describes these studies, their methods and results in more detail.

### *4.1 Interpretation of cost estimate*

The first experimental study investigated the decision maker's interpretation of uncertain costing information. This section presents a summary of the study with regard to the method and results.

#### *4.1.1 Method*

The study was carried out at a one-day conference which was organised by the Society of Cost Analysis and Forecasting [SCAF] and was attended by costing experts from the UK aerospace and defence sectors [SCAF, 2011]. Forty-four experts (out of 52 attendees at the conference) participated in the experiment, in other words they provided answers to both questionnaires. The participants were assigned to the three groups as follows: 13 to group A, 15 to B and 16 to C.

The first experimental study tested three approaches to displaying uncertain costing information, namely a three-point trend forecast, a bar chart with minimum, medium and maximum estimates, and a fan diagram. These were given to three different groups of

participants. Figure 4 shows the tested approaches. Each of the graphs displayed past data on the monthly cost of a raw material, together with the forecasts. It consisted of the same information and labels providing a forecast scenario with minimum, medium and maximum values. The cost data was artificially generated so that the observations were distributed randomly around a linear upward, 'flat' or downward trend.

Based on the graphical display, the participants were given questionnaires which contained a scenario and a set of questions; these were also the same for the three groups. The scenario presented the participants to be a manager at a company hoping to introduce a new product. The cost of this product was assumed to be highly dependent on the cost of the raw material, the forecast of which was presented in the graphs depicted in Figure 4. This product-focused scenario was used due to expertise and experience of the participants, which was still product focused at the time the experiment was carried out.

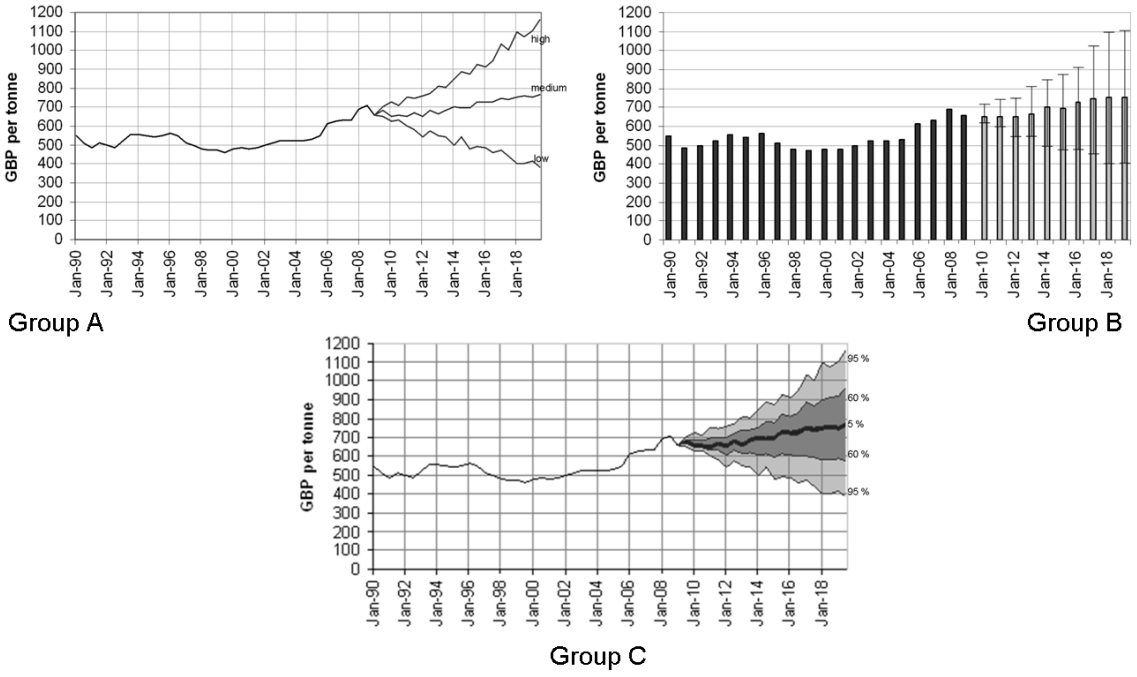


Figure 4: Tested approaches to displaying uncertain costing information

These questions were aimed at the participants' understanding, interpretation and use of the presented costing information. In particular, they were asked to give a cost estimate for

the raw material at two separate points in the future (2014 and 2018), a confidence level associated with these estimates and their reasoning behind the given values. The answers for the confidence levels were given as one of six discrete intervals: 0-20%, 21-40%, 41-50%, 51-60%, 61-80% and 81-100%. The question about the participants' reasoning was asked open-endedly, i.e. they could use their own wording for this question.

The answers were then compared between the three groups to deduce the participants' interpretation of the uncertain information as described in the following section.

### *4.1.2 Results*

Table 2 summarises the participants' answers regarding the chosen cost estimate, connected confidence level and reasoning. The values given in Table 2 indicate the most likely answers, i.e. the ones most frequently observed.

Table 2: Summary of results of first experimental study

| | **Group A** | **Group B** | **Group C** |
|---|---|---|---|
| **Cost estimates** | Medium | Medium-high | Medium-high |
| **Confidence level** | 21-60% | 21-40% | 0-20% |
| **Reasoning** | ***The two most frequently given reasons were:*** <br>• The medium point as the most likely to occur. <br>• The subjective interpretations of the future development of the world economy. | ***The most frequently given reason was:*** A conservative answer, which includes the highest cost estimate or a point between medium and high. | ***The most frequently given reason was:*** The existence and influence of uncertainty was explicitly mentioned. |

The results showed that the decision makers can be influenced in their recognition and consideration of the uncertainty connected to the cost estimate. In particular, the approach for displaying the uncertain cost information can influence this subjective decision process. The three tested approaches were interpreted differently by the costing experts. The

participants who were presented with the fan diagram were less confident in their estimates and identified uncertainty as a major factor on the cost estimation outcome. It was most effective in raising awareness of the uncertainty associated with the decision problem. Thus, the fan-diagram was used in the second experimental study, presented in the following section.

### *4.2 Influence of cometition*

The second experimental study investigated the influence of the competitive environment on the decision maker and the pricing decision at the bidding stage. Again, first the study method is described before the results are summarised.

#### *4.2.1 Method*

The second experimental study was carried out at a conference of SCAF [SCAF, 2011] and at a conference of the Association of Cost Engineers [ACostE] [ACostE, 2010]. These are the two main societies of industrial cost engineers in the UK. Thus, the participants between the first experimental study presented in Section 4.1 and the second one have similar characteristics but were not the same. In this study, the total number of returned questionnaires was 39 for questionnaire 1 and 32 for questionnaire 2 out of which 28 were traceable, i.e. the participants' replies for questionnaire 1 and 2 could be compared.

The study tested the influence competition may have on the decision-making process at the bidding stage. This was undertaken with two questionnaires, each containing the same general scenario which differed in the existence of competition for the included service contract. The two questionnaires were handed out with a time difference to prevent the participants remembering their answers in detail. However, the aim was to keep the participants in the same decision context to limit the influence of change in emotions or stress levels [Schwarz, 2000; Cannon-Bowers, 1998].

The scenario focused on the bidding for a five-year service contract for a lathe machine and contained a qualitative description of the decision problem and a graphical display of the cost forecast. For this, a fan diagram was used as this was found to raise awareness and understanding of the participants with regard to the influence of uncertainty on the decision outcome (see "group C" in Figure 4). The questions focused on the following areas: the participants were asked to give a cost estimate for the contract, a first price bid, a minimum price below which they would not accept the contract and a list of uncertainties that influenced the participants' decisions.

### *4.2.2 Results*

Table 3 summarises the results of the experimental study by stating the percentage of participants who reduced their stated values, raised them or kept them level. In addition the influencing uncertainties on their decision are listed.

Table 3: Summary of results of second experimental study

| | **Changes between questionnaires 1 and 2** | | |
|---|---|---|---|
| | **Reduction** | **Raise** | **Level** |
| **Cost estimate** | 39.3% | 3.6% | 57.1% |
| **First price bid** | 25% | 20.8% | 51.2% |
| **Minimum price bid** | 20.8% | 20.8% | 58.3% |
| **Influencing uncertainties** | • ***Market uncertainties:*** Inflation, future trends, economic changes, technological development, cost increases in material costs and spare parts.<br>• ***Uncertainties in cost estimation:*** Inaccuracy of cost estimate, uncertainty of bounding the estimate, uncertainty in labour rates, uncertainty in maintenance costs.<br>• ***Product uncertainties:*** Performance of machine, aging, risk of failures, experience with machine.<br>• ***Competition uncertainty:*** Risk of loss of contract, competitors' experience with machine.<br>• ***Customer-related uncertainties:*** Utilisation rates of the machine, future contracts and further orders. | | |

In total, 67.9% of the participants changed one of the three values. The results show that

the participants changed their decision when competition was introduced to the bidding scenario; however, the direction of that change was very uncertain. Based on the study results, it is hard to predict a decision maker's reaction to the existence of competition for the service contract. In addition, the participants were able to express the uncertainties that influenced their decision-making process. Each of the five categories named in Table 3 should be included in a framework depicting the uncertainties at the competitive bidding stage.

### *4.3 Consideration of uncertainty*

The third empirical study was an interview study which investigated the whole pricing decision-making process as highlighted in Figure 3, i.e. the interpretation of the cost estimate, the further consideration of uncertainty and the influence of the competitive environment. The aim of this study was to investigate the availability of relevant information in the decision-making process on the supplier's side.

#### *4.3.1 Method*

The interview study was carried out over a period of one year during the rebound period after the global economic recession of 2008-09. The interview was standardised and open-ended which means that the wording and sequence of questions was determined in advance. Thus, each interviewee was asked the same questions in the same order. The answers were not recorded as most interviewees were from organisations in the defence sector or not comfortable with recording. However, the researcher undertaking the study took notes during the process, which were returned to the participants after the interview for confirmation and validation to ensure the correctness of the given information [Robinson et al., 2007].

The nine interviews participating in this study were from the following sectors: four interviewees were from aerospace and defence, two from engineering, and one each in research, information technology, and construction. The interviewees were involved in the preparation of competitive bids for their companies, in particular for services that were product-centred, both of tangible products, such as buildings or airplanes, and intangible products, such as computer software or the outcome of a research project [Vargo and Lusch, 2008; Hill, 1999].

The interviews were semi-structured, i.e. the wording and sequence of questions was determined in advance, thus, each interviewee was asked the same questions in the same order. They followed a standardised procedure with open questions that investigated the input information for the pricing decision and bidding strategy. In particular, the questions investigating the input information examined the available information about the competitors and the customer. The questions about the competitors focused on the knowledge of their identity, their cost estimates for the service contracts to be bid for, the availability of possible special technology, and the decision makers' consideration of this information in the decision-making process. The questions investigating the input information about the customer focused on the customer's bidding strategy, the past relationship between the bidding company and the customer, their future needs and the decision makers' consideration of this information in the decision-making process. The results are described in the next section.

*4.3.2 Results*

The available information concerning the customer considered their bidding strategy (in particular their budget limitations and their evaluation criteria of the competitive bids) and their possible future needs. The answers regarding the customer's bidding strategy indicated two categories: either they were communicated during the bidding process, i.e.

their budget limitations and evaluation criteria were included in the bidding material, or they could be assessed during a "getting-to-know-the-client" process. Of the nine interviewees, four stated that the customer's bidding strategy was communicated, two said it could be assessed, and three said it varied between these two categories depending on the kind of customer. The assessment of the customer's future needs caused different reactions from the interviewees. One part (seven out of nine interviewees) stated that this was important part of the bid compilation process because it could lead to follow-up work and future relations. The other two interviewees highlighted that possible future needs would be very speculative, and, thus, not included in the bid-compiling process.

Regarding the competitors, the interviewees were asked whether they would know their identities for the specific bidding situation, their cost estimates and their available technology/knowledge. Depending on the bidding process, the competitors' identities may be known. For example, if the bidding process included two stages, where the suppliers first had to express their interest in the contract to be shortlisted for the submission of a competitive bid, the competitors would usually know each other's identity. If this was not the case, the interviewees indicated that they may have a "pretty good" idea due to their experience about who would be capable of dealing with the requirements. In other cases, particularly bidding in new market segments where their experience is limited, they would not be able to identify possible competitors at all.

Depending on the bidder's knowledge of their competitors' identity, they would also be able to identify probable values for the competitors' cost estimates and their available technology as presented in Table 4. If the competitors' identity is not known or knowable, the remaining two points would also not be known. The competitors' cost estimates are not usually known to the bidding company, which was confirmed by all interviewees. However, there are different levels of speculation. Based on previous

experiences, a “ballpark” or top level deduction may be known. Another possibility was the knowledge of cost details such as salaries based on information obtained from previous employees of the competitor.

A common answer regarding the competitors’ available technology was that it was known as the competitors advertise themselves on e.g. the internet or have other publicity in e.g. newspapers. This was stated by seven of the nine interviewees. Two interviewees stated that this aspect of the competitors is knowable due to the decision maker’s experience in the area. Thus, it can be summarised that, particularly when a company is bidding in a market sector they have had experience in, they know their potential competitors and are able to characterise them.

Table 4: Available information about the competitors at the bidding stage

| | | | **Identity of competitors** | | |
|---|---|---|---|---|---|
| | | | **Known** | **Knowable** | **Not known** |
| | | **Total** | **7** | **7** | **2** |
| **Value of competitors’ cost estimates** | **Top level costs** | **6** | 6 | 6 | - |
| | **Cost details** | **2** | 2 | 2 | - |
| | **No** | **2** | 1 | 2 | 2 |
| **Competitors’ availability of technology and/or knowledge** | **Known** | **6** | 6 | 4 | - |
| | **Knowable** | **3** | 2 | 3 | - |
| | **Not known** | **2** | - | - | 2 |

These studies were used to induce the framework depicting the uncertainty influencing the pricing decision at the competitive bidding stage. This is described in the following section.

### *4.4 Combination into a framework*

To derive a framework depicting the uncertainties influencing the decision-making process

at the competitive bidding stage for service contracts, the results of the three empirical studies presented in Section 4 were taken as a basis. Table 5 summarises the results.

Table 5: Summary of the results of the three empirical studies

| **Study focus** | **Method** | **Results** |
|---|---|---|
| 1) Interpretation of cost estimate | Experimental survey of practitioners with questionnaires | The uncertainty from the cost estimate and the approach to presenting this information influences the decision maker's perception of the uncertainty connected to it and the inclusion of this perception in the decision-making process. |
| 2) Influence of competition | Experimental survey of practitioners with questionnaires | The influencing uncertainties can be categorised as follows:<br>• Context related: service requirements, product specifications and performance, market and economy<br>• Company related: cost estimate, expanded contract portfolio of the bidding company<br>• Customer related: budget limitations, possible future contracts with customer<br>• Competition related: competitors' identities, competitors' experience with similar services |
| 3) Consideration of uncertainty | Interview study with practitioners | The influencing uncertainties can be categorised as follows:<br>• Company related: service design, cost estimate, expanded contract portfolio of the bidding company<br>• Customer-related: budget limitations, evaluation criteria for the bids<br>• Competition-related: Competitors' identities, cost estimates, available technology/knowledge, experience with similar services |

The first experimental study focused on the uncertainty arising from the cost estimate and the decision maker's interpretation of it. It was found that the uncertainty connected to the cost estimate forms an important influence on the decision-making process at the competitive bidding stage.

In the second empirical study further uncertainties were identified to influence the pricing decision. These can be categorised according to their relation to the service contract and bidding company into company-related, context-related, customer-related and competition-related uncertainties. Company-related uncertainties include the cost estimate and the contract portfolio of the bidding company, i.e. other possibilities to secure profit.

Context-related uncertainties are connected to the service requirements, the product specifications and performance, and the uncertainties connected to the specific market and the economy in general. Another important influence is the customer, in particular their budget limitation and the possibility of future contracts. Further uncertainties include the identities of the competitors for the specific service contract and their experience with similar services.

This was supported with the results of the third empirical study, i.e. the interviews with industry. Using the same classification as for second experimental study, the influencing uncertainties can be summarised as follows. The influences mentioned by the interview participants confirmed some of the uncertainties identified by the first and second experimental studies. Further company-related uncertainties include the service design. Furthermore, the customer's criteria for evaluating the competitive bids were named as an influencing uncertainty. The uncertainties related to the competition were named as the competitors' identities, their cost estimates - or the bidding company's assessment of them, and the competitors' available technology or knowledge.

This means that the uncertainties identified through the empirical studies can be grouped into four influencing factors. Comparing these results to the Balanced Scorecard described in Section 2, the names of these factors can be identified. The context-related uncertainties can be described more accurately as the service contract conditions. The company-related uncertainties can be named as the internal company processes, as they include all the activities necessary to be able to submit a competitive bid. The customer and competitor-related uncertainties can be referred to simply as the "customer" and the "competitors". Thus, the four factors for the uncertainties influencing the bidding strategy are: the service contract conditions, the internal company processes, the customer and the competitors.

The ***service contract conditions*** form the context of the bidding situation including the contract and the service requirements. The contract requirements are defined by the contract type with the negotiation style, the payment method, and the contract scope. The negotiation style of a contract describes, for example, if there is a first round where only the lowest price bids will be accepted for further negotiation [Lehman, 1986]. The payment method defines what sort of price bid is required: a fixed contract price or a cost-plus payment [Tseng et al., 2009; Paul and Gutierrez, 2005]. These two characteristics can be expected to be set by the customer in advance and be influenced by industry standards and customs. The contract scope describes what is included in the contract, in other words what decision rights and organisational activities are transferred to the supplier [Sorrell, 2007]. The service requirements include the problem description for which the customer is seeking a solution with the service contract. They define the specific service to be bid for.

The ***internal company processes*** consider the capabilities and limitations of the bidding company such as their ability to deal with a contract of the required complexity. If it cannot fulfil a contract of the quality or quantity asked for, the process may result in the decision not to bid [de Boer et al., 2001]. Values and issues raised can influence essential points of the bidding process. The central aspect of this factor is the creation of a service design and the cost forecast for the service contract being bid for.

Similar to the potential suppliers, the ***customer*** can be expected to have a bidding strategy [Tulloch, 1980; Harrington Jr., 2009]. This includes the customer's budget limits, their long-term business goals, short-term contract goals, and the customer's evaluation of the service quality. The bidding company may be able to base its decision on the past relationship with the customer and the possibility of a future relationship.

On the single contract level, the existence of ***competitors*** is not abstract and anonymous as it is on the level of business strategy. For a specific contract, the number

and identity of the competing companies may be known or knowable. Furthermore, the portfolio of supplied products and services is usually marketed by a company which means that it is known to competing companies. Given this level of knowledge, the bidding company may evaluate its competitive advantage for the specific service contract.

## 5. Uncertainty framework for competitive bidding

The uncertainty arising from the four factors influencing the bidding strategy, service contract conditions, internal company processes, customer, and competitors can be summarised in a conceptual framework which is depicted in Figure 5.

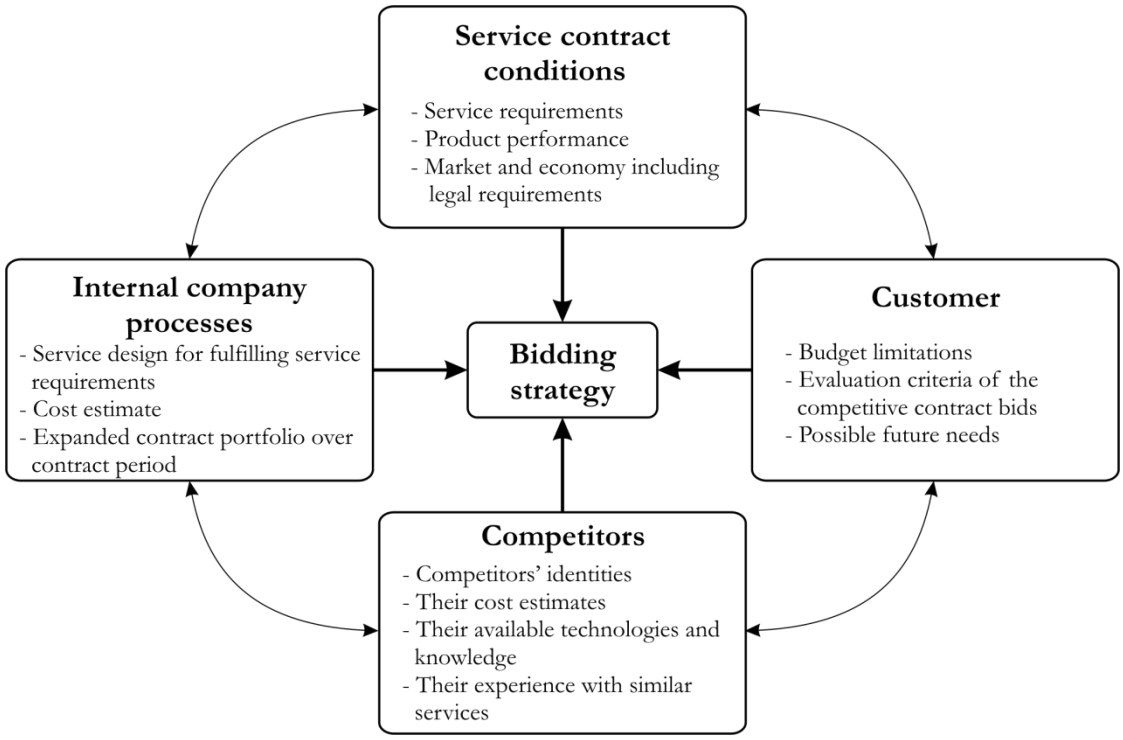


Figure 5: Uncertainty framework for bidding strategy

Figure 5 indicates that the factors can be interlinked. For example, if the bidding company is uncertain about the service requirements (service contract conditions), the service design and cost forecast (internal company processes) may be more uncertain. The framework highlights the most important uncertainties as identified during the three empirical studies.

The following section describes how the uncertainty in each of the four factors can be characterised.

The uncertainties within these four factors can be characterised according to their level of severity. Four different levels of uncertainty have been distinguished, namely deterministic (level 1), set (level 2), interval (level 3) and ignorance (level 4) [Courtney, 2001]. Under level-1 uncertainty, the future is sufficiently clear so that the outcome is predictable enough for a confident decision. In level 2, a set of possible future outcomes can be distinguished, one of them will occur. Under level-3 uncertainty, a range of possible future outcomes may occur, i.e. the outcome can be bound between a maximum and a minimum value. The highest level of uncertainty is characterised by total ignorance [Walker et al., 2003; Ayyub, 2004] where the future outcomes can be described as unknown and unknowable. These four levels are used to describe the uncertainty in the conceptual framework.

### *5.1 Service contract conditions*

The service contract conditions define aspects such as the general bidding process, payment method, and the contract scope which can cause uncertainty in the bidding process. These are either subject to conduct of the market segment, the particular customer, or they are defined prior to the bidding procedure.

The service requirements may be subject to uncertainty particularly when the customer is not able to define or even indicate them precisely. This uncertainty is usually accounted for with the bidding process. In cases where the service requirements are clear [Baines et al.] to the point that the customer knows the aims of the service and can communicate them precisely, there is little uncertainty connected to them. In cases where the service requirements may be unclear, e.g. the customer can only define the service aims

vaguely or the way of communication leaves the bidding supplier uncertain, the bidding process usually includes some form of negotiation. This means that this uncertainty can be reduced through further communication and discussion with the customer.

Further uncertainty is the product performance which includes, for example, the utilisation rate of the serviced product or the service history such as previous repairs. In cases where the bidding process includes negotiation, the bidding company may obtain information regarding these influences. In other cases, the contract may include specifications such as maximum utilisation rates which limit the uncertainty. However, due to the phenomenological character of this influence, the uncertainty cannot be reduced completely. For example, the customer may not be able to forecast with complete certainty how much they will use or need to use the product in 5 years. Thus, there is uncertainty regarding the product performance at the bidding stage, the level of this uncertainty may vary due to contractual commitments.

In addition, market and economic uncertainties can influence the service contract conditions over the contract period. These uncertainties can include possible legal changes, the economic situation in general, and the specific market segment. Assuming that they are assessed over the period of the service contract, they can usually be bound to an interval of possible future values; however, it is also possible that the bidding company has to act under ignorance concerning these aspects. In general both parties, the customer and the bidding supplier, have an incentive to reduce the uncertainties of the service contract conditions to establish a service that fulfils their needs best [Goldberg, 1977; Yee and Korba, 2003; Tung and Lin, 2005; Bajari et al., 2008].

### *5.2 Internal company processes*

The uncertainties within the factor of the internal company processes can be connected to

the service design, the cost estimate and the company's contract situation. The bidding company may be uncertain about the service design, in other words the activities to fulfil the service requirements. The service design forms a basis for the cost estimate and the pricing decision process (see Figure 3). Thus, the uncertainty connected to these two aspects of the internal company perspective are interlinked, however, not mutually exclusive. Important assumptions, that had to be made, include, for example, the customer's utilisation rates of the serviced machine, the frequency of necessary repairs, and the duration of maintenance activities. The connected uncertainty to the service design may vary depending on the available information about the service activities. However, it is unlikely that a company would be included in the bidding process if it had no experience in the area, in other words if it was ignorant of the service design.

In cost-based pricing, the cost estimate is an important influence on the price bid as it forms the basis of the estimation of the profit and price connected to the service contract to be bid for. The uncertainty connected to the cost estimate may be depicted explicitly in the form of a range or is included implicitly through assumptions that may not prove true. For a pricing decision, the uncertainty connected to the cost estimate arises from the decision maker's interpretation of the modelled results [Kreye et al., 2012; Wang et al., 2007]. Thus, it is typically of an epistemic nature and caused by a lack of information about the future.

The uncertainty connected to the company's contract portfolio can be influenced by the bidding company and forms the context of current and future decisions. For example, a company can influence what percentage of its contract portfolio it would earn through short-term consultancy agreements or through long-term capability contracts. Through the empirical studies, the contract portfolio was identified to be of less importance in the decision process than the uncertainty arising from the cost estimate. However, it can

influence the strategic evaluation of the price bid particularly in the formulation of the minimum bid. The contract situation is only examined for the implementation period of the service contract to be bid for. Depending on the usual contract length, the level of the uncertainty is either deterministic (level 1), if the company holds many long-term contracts, or it can only be bound as an interval (level 3), if the company maintains a majority of short-term contracts. If the bidding company holds a portfolio of contracts, the uncertainty level can also be described as a set (level 2).

### *5.3 Customer*

The uncertainty connected to the customer can arise from their budget constraints, their evaluation criteria for the submitted bids and possible future needs. If the customer's budget limit is communicated, it may still cause the bidding company to be uncertain regarding its enforcement [Leopoulos and Kirytopoulos, 2004]. For example, a customer may award their service contracts typically 5% lower than the stated budget or may be willing to pay more if the benefits are considered worth it. This means that, where the budget is communicated, there is still a low level of uncertainty connected to it. If the customer's budget limit is not communicated, the bidding company may still be able to put boundaries to it using experience. The experience may be based on analysis of the customer's previous bidders selection for similar projects in order to recognise observable patterns. If this experience is not available (for example when entering a new market sector), the bidding company is ignorant towards the customer's budget limit and cannot model this uncertainty to include it in their decision process.

A similar pattern can be followed for the uncertainty arising from the customer's evaluation criteria. These may be communicated in different levels of detail. In some cases, they may be communicated in a quantitative way stating clearly the importance each

aspect of the bid would receive. In this case, there is a small level of uncertainty connected to the customer's evaluation criteria. In other cases, the criteria may only be communicated in a qualitative way, for example stating the mandatory and optional service requirements. In this case, the uncertainty connected to the customer's evaluation criteria can be characterised as level 2 – set. The bidding company has information about the mandatory service criteria; however, it is still uncertain about the relative importance of the different requirements in relation to each other. Particularly regarding the optional characteristics, the bidding company may remain uncertain as to which options would give them a competitive advantage. If the criteria are not communicated but the bidding company has experience with this customer, they may be able to bound the relative importance of the different service characteristics in an interval. The spread of the interval then depends on the amount of experience. If the bidding company does not have any previous experience with the customer and the criteria are not communicated, it may be ignorant about them.

In addition, uncertainty may arise from the customer's future needs regarding other related services. Being awarded a particular service contract may open further opportunities with this customer. Including possible future benefits into the proposed bid, may raise its perceived quality by the customer and thus give the bidding company a competitive advantage. In general, all four levels of uncertainty are possible depending on the particular market segment and time horizon under consideration. The market sector may be rich in information and slow-moving which means that the future development of the customer can be predicted (level 1 – deterministic). In other cases, the customer may plan to explore new market segments which would increase the uncertainty (level 2 – set). The bidding company may be able to bound this uncertainty (level 3– interval). However, the bidding company may include the customer's future needs when they expect to gain a

competitive advantage. The uncertainties would then consist of set (level 2) or interval (level 3).

### *5.4 Competitors*

The uncertainty arising from the competitors is typically connected to the identification of the competitors for the particular service contract and an evaluation of their most likely bid. In some cases, the competitors' identity is communicated during the bidding process which means that there is a low level of uncertainty connected to this aspect as they might decide not to bid. If this is not the case, the bidding company has to assess their identity based on its experience in the market segment. In this case, the level of uncertainty connected to the competitors' identity may be either set (company has experience in the area but no specific information regarding the competitors' identity) or ignorance (company has no experience in the area).

If the identity of the competitors is not known or knowable, no further knowledge about their possible behaviour is available. In this case, all further assumptions about the competitors have to be made under ignorance.

If the identity of the competitors is or can be known, a top-level guess of their estimated costs may be used. This means that the level of uncertainty arising from the competitors' cost estimates may be bound in an interval. This leads to a high level of uncertainty connected to the competitors' cost estimates which is connected to the fact that the bidding company knows less about the competitors' cost estimates than about their own. However, the information or experience that is available can be used to guide the competitiveness of one's own price bid.

The availability of certain technology or knowledge to a competitor may give them a competitive advantage in that they may be able to offer a better service quality or a

cheaper price (or both). The competitors usually advertise these aspects in the public domain on e.g. their homepage or the newspaper which means that the availability of the competitors' technologies or knowledge is assessable for the bidding company. This suggests that, when the competitors' identity is known, the uncertainty connected to their available technology and/or knowledge is low (level 1- deterministic).

The competitors' experience with similar services can be an important influence on their suitability for the service contract. The uncertainty connected to this can either be described as level 4 – ignorance if the bidding company does not have any experience in the market sector and hence does not know the competitors background, or as level 3 – interval if the company does have experience but lacks detailed information about their competitors' experience.

## 6. Discussion and validation

This paper presented a conceptual framework of the factors which can influence the pricing decision at the bidding stage for service contracts. Based on three empirical studies four factors were identified and the uncertainties within these four factors were described and characterised with regard to their cause and level of severity.

The framework was related to theory in the area of business strategy. Particularly, the Balanced Scorecard framework described by Kaplan and Norton [1996] was used as a basis for the uncertainty framework introduced in this paper. The main criticism of the Balanced Scorecard is its static projection of a company's business strategy [Norreklit, 2000; Mooraj et al., 1999]. In other words, it offers a momentary representation of the company's objectives, targets and performance measures without giving a history or indication of future development. Similarly, the uncertainty framework introduced in this paper offers a static, momentary picture of the uncertainties influencing the pricing

decision. However, the aim of this framework is to offer a conceptual basis to support the decision process at the bidding stage. In other words, it represents the uncertainty at the moment of making the pricing decision.

The described uncertainty framework is applicable to product-centred services that are highly complex, long-lived, delivered from business to business (B2B) and allocated in a competitive environment. Nonetheless, it may also be applicable to services of low complexity such as consultancy. However, to test and validate this broader applicability, further research has to be done.

To validate this framework, it is proposed to use multiple industrial case studies in the area of competitive bidding for complex service contracts. Depending on the specific service contract and bidding context, one or more of the four factors may be emphasised and receive more importance by the bidding company. For example, imaging a competitive bidding scenario where the bidding company has had a long experience with the customer and has a high expertise for providing the specific service. In this case, the bidding company might emphasis the uncertainty connected to their competitors and their possible bids. In contrast, if the bidding company bids for a specific service where it does not have a high level of experience in, it might value the uncertainty connected to the service contract conditions (particularly the requirements) or the customer of higher importance. Hence, the uncertainty framework described in this paper will be validated with multiple case studies in various industrial sectors.

## 7. Conclusions and managerial implications

This paper proposed a conceptual framework depicting the uncertainties influencing the pricing decision at the competitive bidding stage. These uncertainties were summarised in four factors, namely the service contract conditions, internal company processes, customer

and competitors.

The framework can be applied by industry to different service contracts which are allocated through competitive bidding. In particular, the framework can form the basis of the bidding company's evaluation of the importance of the four factors for the specific service contract bidding scenario. Based on this evaluation, the efforts for the collection of necessary information to support the bidding decision can be directed and managed. Through this framework, industrial decision makers can eliminate contracts from further consideration in their portfolio and identify contracts that deserve further attention in the bid compilation process.

Using industrial case study data, the framework can form the basis of uncertainty modelling activities to support the decision-making process at the competitive bidding stage. Particularly the uncertainty connected to the customer and the competitors can be modelled to obtain the probability of winning the contract. This can be depicted in contrast to the probability of making a profit which can be obtained from the uncertainty connected to the cost estimate. The probability of winning the contract and the probability of making a profit can be included in a decision matrix to depict the trade-offs between the two functions and guide the selection of a suitable price bid for the specific service contract. This will form the next steps in this research project.

**Acknowledgements:** The authors gratefully acknowledge the support provided by the Innovative Design and Manufacturing Research Centre (IdMRC) at University of Bath, UK funded by the Engineering and Physical Science Research Council (EPSRC) under Grant No. GR/R67507/01 for the research reported in this paper. The authors would also like to acknowledge the contribution by the reviewers, which have made this a better and more concise paper.

## References

Association of Cost Engineers, 2010. *ACostE Conference 2010* [online]. Available from: http://www.acoste.org.uk/template_content_F.php?page_id=481&track=Conference [accessed 25/10/2011].

ADLER, P. S., 2001. Market, Hierarchy, and Trust: The Knowledge Economy and the Future of Capitalism. *Organization Science,* 12(2), 215-234.
AFUAH, A., 2009. *Strategic Innovation - New Game Strategies for Competitive Advantage*, New York, NY, USA, Routledge.
AGRAWAL, V. & SESHADRI, S., 2000. Impact of Uncertainty and Risk Aversion on Price and Order Quantity in the Newsvendor Problem. *Manufacturing and Service Operations Management,* 2(4), 410-423.
AL-ASHAAB, A., FLORES, M., DOULTSINOU, A. & MAGYAR, A., 2011. A balanced scorecard for measuring the impact of industry-university collaboration. *Production Planning and Control,* 22(5-6), 554-570.
AURICH, J. C., FUCHS, C. & WAGENKNECHT, C., 2006. Life Cycle Oriented Design of Technical Product-Service Systems. *Journal of Cleaner Production,* 14(17), 1480-1494.
AYYUB, B. M., 2004. From Dissecting Ignorance to Solving Algebraic Problems. *Reliability Engineering and System Safety,* 85(2004), 223–238.
BAE Systems, 2012. *UK Hawk Support* [online]. Available from: http://www.baesystems.com/product/BAES_019769/uk-hawk-support [accessed 04 April 2012].
BAINES, T., LIGHTFOOT, H., PEPPARD, J., JOHNSON, M., TIWARI, A., SHEHAB, E. & SWINK, M., 2009. Towards an operations strategy for product-centric servitization. *International Journal of Operations and Production Management,* 29(5), 494-519.
BAINES, T. S., LIGHTFOOT, H. W., EVANS, S., NEELY, A., GREENOUGH, R., PEPPARD, J., ROY, R., SHEHAB, E., BRAGANZA, A., TIWARI, A., ALCOCK, J. R., ANGUS, J. P., BASTL, M., COUSENS, A., IRVING, P., JOHNSON, M., KINGSTON, J., LOCKETT, H., MARTINEZ, V. & MICHELE, P., 2007. State-of-the-art in Product-Service Systems. *Proceedings of the Institution of Mechanical Engineers - Part B - Journal for Engineering Manufacture,* 221(2007), 1543-1552.
BAJARI, P., MCMILLAN, R. & TADELIS, S., 2008. Auctions Versus Negotiations in Procurement: An Empirical Analysis. *Journal of Law, Economics, & Organization,* 25(2), 372-399.
BERKLEY, B. J., 1996. Analyzing Service Blueprints Using Phase Distributions *European Journal of Operational Research*, 88(1996), 152-164.
BONTIS, N., DRAGONETTI, N. C., JACOBSEN, K. & ROOS, G., 1999. The Knowledge Toolbox: A Review of the Tools Available to Measure and Manage Intangible Resources. *European Management Journal,* 17(4), 391-402.
CANNON-BOWERS, J. A., 1998. *Making Decisions under Stress: Implications for Individual and Team Training*, Washington, DC, USA, American Psychological Association.
CHAPMAN, C. B., WARD, S. C. & BENNELL, J. A., 2000. Incorporating Uncertainty in Competitive Bidding. *International Journal of Project Management,* 18(5), 337-347.
COUGHLAN, J., MACREDIE, R. D. & PATEL, N., 2011. Understanding the consumption process through in-branch and e-mortgage service channels: A first-time buyer perspective. *International Journal of Bank Marketing,* 29(2), 148-167.
COURTNEY, H., 2001. *20/20 Foresight: Crafting Strategy in an Uncertain World* Harvard Business School Press.
DE BOER, L., LABRO, E. & MORLACCHI, P., 2001. A Review of Methods Supporting Supplier Selection. *European Journal of Purchasing & Supply Management*, 7(2), 75-89.

DURANGO-COHEN, E. J. & YANO, C. A., 2011. Optimizing customer forecasts for Forecast-Commitment contracts. *Production and Operations Management,* 20(5), 681-698.
ENQUIST, B., CAMEN, C. & JOHNSON, M., 2011. Contractual governance for public service value networks. *Journal of Service Management,* 22(2), 217-240.
FORNASIERO, R., ZANGIACOMI, A. & SORLINI, M., 2012. A cost evaluation approach for trucks maintenance planning. *Production Planning and Control,* 23(2-3), 171-182.
FREEDMAN, A. M. (1988): *A Price That's Too Good May Be Bad*. In: The Wall Street Journal, 15 November, pp.
GOLDBERG, V. P., 1977. Competitive Bidding and the Production of Precontract Information. *The Bell Journal of Economics,* 8(1), 250-261.
GOLDSTEIN, S. M., JOHNSTON, R., DUFFY, J. & RAO, J., 2002. The Service Concept: The Missing Link in Service Design Research? *Journal of Operations Management,* 20(2), 121-134.
GRÖNROOS, C. & HELLE, P., 2010. Adopting a service logic in manufacturing Conceptual foundation and metrics for mutual value creation. *Journal of Service Management,* 21(5), 564-590.
HAIMES, Y. Y., 2009. *Risk Modeling, Assessment, and Management,* Hoboken, NJ, USA, John Wiley and Sons.
HARRINGTON JR., J. E., 2009. *Games, Strategies, and Decision Making,* New York, NY, USA, Worth Publishers.
HESKETT, J. L., JONES, T. O., LOVEMAN, G. W., SASSER, W. E. J. & SCHLESINGER, L. A. (2008): *Putting the service-profit chain to work*. In: Harvard Business Review, July-August, pp. 118-129.
HILL, P., 1999. Tangibles, Intangibles and Services: A New Taxonomy for the Classification of Output. *The Canadian Journal of Economics / Revue canadienne d'Economique,* 32(2), 426-446.
HOLSCHBACH, E. & HOFMANN, E., 2011. Exploring quality management for business services from a buyer's perspective using multiple case study evidence. *International Journal of Operations & Production Management,* 31(6), 648-685.
HUA, G., WANG, S. & CHENG, T. C. E., 2012. Optimal order lot sizing and pricing with free shipping. *European Journal of Operational Research,* 218(2), 435-441.
HUANG, W. H. & LIN, T., 2011. Developing effective service compensation strategies: Is a price reduction more effective than a free gift? *Journal of Service Management,* 22(2), 202-216.
HUYSE, L. & WALTERS, R. W. (2001): *Random Field Solutions Including Boundary Condition Uncertainty for the Steady-Stae Generalized Burgers Equation*. Report, ICASE NASA Langley Research Center, Hampton, Virginia, NASA/CR-2001-211239 ICASE/2001-35.
KAPLAN, R. S. & NORTON, D. P., 1996. *The Balanced Scorecard: Translating Strategy into Action,* Boston, MA, USA, Harvard Business School.
KREYE, M. E., GOH, Y. M., NEWNES, L. B. & GOODWIN, P., 2012. Approaches of Displaying Information to Assist Decisions under Uncertainty. *Omega - International Journal of Management Science,* 40(6), 682-692.
LAWRENCE, M., GOODWIN, P., O'CONNOR, M. & ÖNKAL, D., 2006. Judgmental Forecasting: A Review of Progress Over the Last 25 Years. *International Journal of Forecasting,* 22(3), 493-518.
LEHMAN, D. H., 1986. Technique for Lowering Risks During Contract Negotiations. *IEEE Transactions on Engineering Management,* 33(2), 79-81.

LEOPOULOS, V. N. & KIRYTOPOULOS, K. A., 2004. Risk Management: A Competitive Advantage in the Purchasing Function. *Production Planning & Control,* 15(7), 678-687.
LEWIS, M., BRANDON-JONES, A., SLACK, N. & HOWARD, M., 2010. Competing through operations and supply: The role of classic and extended resource-based advantage. *International Journal of Operations & Production Management,* 30(10), 1032-1058.
LIU, N. C., ROTH, A. V. & RABINOVICH, E., 2011. Antecedents and consequences of combinative competitive capabilities in manufacturing. *International Journal of Operations & Production Management,* 31(12), 1250-1286.
MAGUIRE, S., OJIAKO, U., PAPADOPOULOS, T., SHAFTI, F., KOH, L. & KANELLIS, P., 2012. Synchronicity and alignment of productivity: The real value from services science? *Production Planning and Control,* 23(7), 498-512.
MONROE, K. B., 2002. *Pricing: Making Profitable Decisions,* New York, NY, USA, McGraw-Hill/Irwin.
MOORAJ, S., OYON, D. & HOSTETTLER, D., 1999. The Balanced Scorecard: A Necessary Good or an Unnecessary Evil? *European Management Journal,* 17(5), 481-491.
NEELY, A., 1999. The Performance Measurement Revolution: Why Now and What Next? *International Journal of Operations & Production Management,* 19(2), 205-228.
NEELY, A., 2008. Exploring the Financial Consequences of the Servitization of Manufacturing. *Operations Management Research,* 1(2), 103-118.
NORREKLIT, H., 2000. The Balance on the Balanced Scorecard: A Critical Analysis of Some of Its Assumptions. *Management Accounting Research,* 11(1), 65-88.
OLIVA, R. & KALLENBERG, R., 2003. Managing the Transition from Products to Services. *International Journal of Service Industry Management,* 14(2), 160-172.
PAUL, A. & GUTIERREZ, G., 2005. Simple Probability Models for Project Contracting. *European Journal of Operational Research,* 165(2), 329-338.
RAINEY, H. G., 2003. *Understanding and Managing Public Organizations,* San Francisco, CA, USA, John Wiley & Sons.
ROBINSON, H., SEGAL, J. & SHARP, H., 2007. Ethnographically-informed Empirical Studies of Software Practice. *Information and Software Technology,* 49(6), 540-551.
2011a. *Global Support Network* [online]. Available from: http://www.rolls-royce.com/marine/services/global_support_network/index.jsp [accessed 25/10/2011].
2011b. *Submarines Propulsion* [online]. Available from: http://www.rolls-royce.com/marine/about/market_sectors/submarines/submarines_propulsion/ [accessed 25/10/2011].
2011. *Society for Cost Analysis and Forecasting* [online]. Available from: http://www.scaf.org.uk/ [accessed 25/10/2011].
SCHWARZ, N., 2000. Emotion, Cognition, and Decision Making. *Cognition and Emotion,* 14(1), 433-440.
SOANES, C., 2005. *The Oxford English Dictionary,* Oxford, UK, Oxford University Press.
SORRELL, S., 2007. The Economics of Energy Service Contracts. *Energy Policy,* 35(1), 507-521.
SU, X. & MUKHOPADHYAY, S. K., 2012. Controlling power retailer's gray activities through contract design. *Production and Operations Management* 21(1), 145-160.
TAY, A. S. & WALLIS, K. F., 2000. Density Forecasting: A Survey. *Journal of Forecasting,* 19(4), 235-254.

TEBBENS, R. J. D., SANGRUJEE, N. & THOMPSON, K. M., 2006. The Costs of Future Polio Risk Management Policies. *Risk Analysis,* 26(6), 1507-1531.
TSENG, F.-S., TANG, K., MOSKOWITZ, H. & PLANTE, R., 2009. Maintenance Outsourcing Contracts for New Technology Adoptions. *IEEE Transactions on Engineering Management,* 56(2), 203-218.
TULLOCH, A., 1980. Is Competitive Price Bidding for Professional Services Practical? *ASCE - Journal of Professional Issues in Engineering,* 106(1), 57-61.
TUNG, H.-W. & LIN, R. J. (2005): *Automated Contract Negotiation Using a Mediation Service*. In: CEC 2005 - Seventh IEEE International Conference on E-Commerce Technology, 19-22 July, München, Germany.
VAN DER VALK, W., WYNSTRA, F. & AXELSSON, B., 2009. Effective buyer-supplier interaction patterns in ongoing service exchange. *International Journal of Operations & Production Management,* 29(8), 807-833.
VARGO, S. L. & LUSCH, R. F., 2004. Evolving to a new dominant logic for marketing. *Journal of Marketing,* 68(1), 1-17.
VARGO, S. L. & LUSCH, R. F., 2008. Service-dominant Logic: Continuing the Evolution. *Journal of the Academy of Marketing Science,* 36(1), 1-10.
VICEIRA, L. M., 2012. Bond risk, bond return volatility, and the term structure of interest rates. *International Journal of Forecasting,* 28(1), 97-117.
WALKER, W. E., HARREMOES, P., ROTMANS, J., VAN DER SLUIJS, J. P., VAN ASSELT, M. B. A., JANSSEN, P. & KRAUSS, K. V., 2003. Defining Uncertainty: A Conceptual Basis for Uncertainty Management in Model Based Decision Support. *Integrated Assessment* 4(1), 5-17.
WANG, W.-C., DZENG, R.-J. & LU, Y.-H., 2007. Integration of Simulation-based Cost Model and Multi-criteria Evaluation Model for Bid Price Decisions. *Computer-Aided Civil and Infrastructure Engineering,* 22(3), 223-235.
WANG, W. C., WANG, S. H., TSUI, Y. K. & HSU, C. H., 2012. A factor-based probabilistic cost model to support bid-price estimation. *Expert Systems with Applications,* 39(5), 5358-5366.
YANG, D., XIAO, T. & SHEN, H., 2009. Pricing, service level and lot size decisions of a supply chain with risk-averse retailers: implications to practitioners. *Production Planning & Control,* 20(4), 320-331.
YEE, G. & KORBA, L. (2003): *Bilateral E-Services Negotiation Under Uncertainty*. In: SAINT 2003 - International Symposium on Applications and the Internet, 27-31 January Orlando, Florida, USA.
YIU, C. Y. & TAM, C. S., 2006. Rational under-pricing in bidding strategy: a real options model. *Construction Management & Economics,* 24(5), 475-484.